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ARTIFACT IDENTIFICATION AND ASSESSMENT
PLUM BROOK REACTOR FACILITY
SANDUSKY, OHIO

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Introduction

Gray & Pape, Inc., conducted documentary research and field investigations at Plum Brook Reactor Facility (PBRF) on 4 and 5 January 2001 for the purpose of identifying and assessing the significance of artifacts associated with the PBRF. NASA Procedures and Guidelines NPG 4310 *Identification and Disposition of NASA Artifacts* (16 March 1999) provides guidance for the identification, reporting, transfer, or disposal of NASA articles, equipment and hardware of historical interest. NPG 4310 defines artifacts as "unique objects that document the history of the science and technology of aeronautics and astronautics." The significance of such objects stems mainly from their relationship to "historic flights, programs, activities, or incidents; achievements or improvements in technology; our understanding of the universe; and important or well-known personalities."

According to NPG 4310, artifacts are identified by NASA Center Property Disposal Officers, working with their respective Public Affairs Offices, program and project directors, and Center Directors. Turn-in documents are prepared that describe the relationship of the artifact to the historically significant program or project. These documents are submitted to NASA Headquarters and the National Air & Space Museum (NASM). The NASM indicates to NASA which artifacts it wishes to acquire and provides shipping instructions. Artifacts that the NASM does not wish to acquire may be disposed of by NASA.

The Plum Brook Reactor Facility occupies a complex of buildings located within a 27-acre fenced area in the northern portion of the 6400-acre Plum Brook Station (see Figure 1). The PBRF (see Figure 2) includes:

- the Reactor Building (Building 1111), containing a 60-megawatt materials test reactor and a 100-kilowatt swimming pool-type mock-up reactor, both of which have been shut down and defueled;
- a seven-cell Hot Laboratory complex (Building 1112);
- reactor and laboratory operations support facilities, including the Reactor Office and Laboratory Building (Building 1141), Primary Pump House (Building 1134), Fan House (Building 1132), Waste Handling Building (Building 1133), Hot Retention Area (1155), Cold Retention Basins (1154), and a hot pipe tunnel; and
- general support facilities, including the Reactor Services Equipment Building (Building 1131) and Reactor Security Building (Building 1191).

Identification efforts focused on the Reactor Building, Hot Laboratory, and Laboratory and Office Building. A 20 December 2000 conference call between NASA, Science Applications International Corporation (SAIC), and Gray & Pape personnel determined that these buildings were the most likely to contain artifacts that met the NPG 4310 definition. Pumps, air filters, heat exchangers, compressors, and the host of other equipment that serviced the reactor and assured its safe operation were not identified. This equipment, while vital to the operation of the facility, is neither unique to the PBRF nor specifically designed for use with a nuclear facility and does not meet the NPG 4310 definition of an “artifact.” Gray & Pape staff concentrated their efforts upon the identification of artifacts directly associated with the reactor and the experiments conducted at the facility.

Overview History of the Plum Brook Reactor Facility

During the 1950s the United States Air Force (USAF) and the Atomic Energy Commission (AEC) initiated a joint series of feasibility studies on the use of nuclear propulsion for aircraft, rockets, and space vehicles. Project Rover, initiated by the AEC in response to a USAF request, concentrated upon the technical feasibility of utilizing nuclear propulsion for rockets. In October 1958 the Executive Order creating NASA from the National Advisory Committee for Aeronautics (NACA) transferred selected support work for Project Rover from the USAF to NASA (Gantz ca. 1960:14).

The proposed nuclear propulsion of rockets substituted a nuclear reactor for the combustion chamber of a chemical rocket. A nuclear rocket would require both nuclear fuel elements for the reactor and liquid rocket fuel. The latter, pumped through the channels of the reactor core, would serve as coolant for the reactor. Heated to high temperatures as it passed through the core, the liquid fuel would be expanded through a conventional rocket nozzle to provide thrust (Gantz ca. 1960:18, 26).

The development of this proposed technology faced three major obstacles:

- current reactor materials were inadequate at the high operating temperatures required to produce the necessary thrust;
- shield weights for current reactor designs were too heavy, greatly diminishing payload weights; and
- materials used in proximity to the reactor were vulnerable to radiation. A situation exacerbated by the need to save shield weight, which led to designs that increased the exposure of these materials to radiation (Lewis Research Center Staff 1959: 3).

In 1955 NACA received funds from Congress to construct a research reactor to study these problems. Construction of the PBRF began in 1956 and required nearly six years. After completion of construction and successful testing of the reactor, the facility became operational in January 1962. The PBRF operated from January 1962 through January 1973. The facility supported NASA’s nuclear rocket and power supply programs by performing irradiation tests of fueled and unfueled experiments for space program applications. Initial experiments included:

- pumped loop studies of performance and behavior of fuel elements and other reactor components at coolant flow, heat flow, neutron flux, and temperature conditions of interest for rockets and space vehicles;

- effects of radiation on reactor materials, and the interaction between reactor materials, structural materials, fluids, and equipment;
- shield studies; and
- nuclear physics and solid state physics experiments pertaining to the development of a nuclear power plant (Lewis Research Center Staff 1959: 3).

Reactor Building (Building 1111)

The Reactor Building is a 4-story, flat roofed, building measuring approximately 150 by 160 feet (see Figures 3 and 4, Plate 1). The Reactor Building houses the reactor and its containment vessel and provides setup and work space around the containment tank at grade level (Plate 2). The building also housed shop and personnel facilities and control panels for experiments. The reactor control room is located on a mezzanine that extends along the north and west walls (Lewis Research Center Staff 1959: 15).

<u>Reactor Description</u>
The principal mission of the PBRF was to determine when irradiated materials and components would fail under various conditions. The facility was designed to permit expedited removal of highly radioactive experiments and test components with minimal hazards or delays in the operation of the facility as a result of the failure of a test object. One design solution used to achieve this goal resulted in providing the reactor with solid shielding only sufficient for the reactor shutdown periods. During testing the remainder of the shielding was provided by a pool of water surrounding the solid shield. The thinness of the solid shield allowed pumped loop equipment to be closely coupled to the test units and eliminated the need for expensive and complicated shielding plugs. A continuous water shielded canals permitted experiments to be moved to the storage and hot cell areas without the use of “coffins” (Lewis Research Center Staff 1959: 4).

The reactor design was a modified version of the Materials Testing Reactor (MTR), located at the National Reactor Testing Station in Arco, Idaho, and placed into service in March 1952. The MTR was designed for the same purpose as the PBRF, to provide facilities for testing materials in high-intensity radiation fields. The MTR was a thermal-neutron reactor that used enriched uranium as a fuel, with water as moderator and coolant, and beryllium as reflector. The unit operated at 30,000 kilowatts (American Society of Mechanical Engineers 1955:153).

The PBRF reactor is mounted in a vertical, cylindrical, stainless steel-clad pressure tank measuring 9 feet in diameter and 32 feet in height (see Figure 5). The top of the tank is at approximately grade level, with the center of the reactor core 21 feet below grade. The reactor pressure tank is surrounded by a solid shield of high density concrete a minimum of 2 feet thick. The remainder of the biological shield, as described above, is provided by a circular pool of water surrounding the pressure tank. The walls of the pool are 3-foot-thick reinforced concrete. The pool is divided into four quadrants by watertight partitions. Three of the quadrants are 25 feet deep, while the fourth has a depth of 27 feet. The shielding pool is enclosed in a 100-foot diameter cylindrical steel containment tank.

Surrounding the pool inside the containment tank, is a concrete-floored work space measuring 13 feet in width (Lewis Research Center Staff 1959: 8-14).

A canal permitted underwater transportation of radioactive materials, equipment, experiments, and fuel elements from the reactor to storage or the Hot Laboratory. The canal, which measures 13 feet wide and 25 feet deep, provided access to 3 of the shielding pool's 4 quadrants. Access from the quadrants to the canal is provided by watertight underwater doors. A watertight underwater door also is located at the point where the canal passes through the containment tank wall. Outside the containment tank the canal passes through the Reactor Building and into the Hot Laboratory. A branch of the canal terminates inside the Reactor Building and served as storage space for fuel elements (Lewis Research Center Staff 1959: 14-15).

<u>Experiments</u>
The large variety of in-pile experiments considered necessary for development of a nuclear reactor suitable for flight applications necessitated the design of 43 test holes that passed in and around the reactor core. Pumped loop fuel element experiments presented the greatest hazard, since these experiments could be intentionally run past the point where the fuel element ruptured. To prevent radioactive releases under these circumstances each experiment was enclosed in an experiment container tank (Lewis Research Center Staff 1959: 85).

These experiments placed fuel elements, cooled by air, sodium, or liquid helium, inside the reactor to determine the effects of radiation upon the fuel elements. Upon removal from the reactor core, the experiments were moved, via the canals, to the Hot Laboratory for dismembering of the experiment and removal of the test fuel element for inspection and analysis (Lewis Research Center Staff 1959: 88-93).

Additional experiments evaluated the effects of radiation upon materials at cryogenic temperatures. Scientists determined that the combination of low temperature – resulting from the use of liquid hydrogen as a propellant – and nuclear radiation – emanating from the reactor powerplant – in a nuclear rocket would produce unknown effects upon the engineering properties of materials. Experiments sought to determine the effects of these conditions upon various materials so that reliable systems could be designed. Material samples were irradiated for various periods and then tested in the Hot Laboratory to determine tensile strength, impact strength, sheer strength, creep strength, fatigue, wear, hardness, ductility, electrical resistivity, and other properties (Lewis Research Center Staff 1959: 97-100).

Hot Laboratory (Building 1112)

The Hot Laboratory is a 2-story concrete building, measuring approximately 104 by 136 feet, attached to the south façade of the Reactor Building (see Figure 6, Plate 3). Immediately adjacent to the Reactor Building is a 40- by 75-foot hot handling room with 72-inch thick concrete walls. This room served as a radiation shield and air lock for most Hot Laboratory operations. The canal from the Reactor Building passes through this room, permitting remote transfer of materials to either seven hot cells or the Hot Dry Storage Area. An uncontaminated work area extends along the west face of the hot cells. At the south end of the building personnel decontamination areas provide access to the semi-contaminated work area and shops located east of the hot cells (Lewis Research Center Staff 1959: 20-21).

Biological shielding was provided by a 48-inch thick magnetite wall along the east and south faces of the hot cells. The rear walls of the hot cells are 63 inches thick. The roofs of the hot cells were shielded by 24 inches of concrete. The only penetrations of the hot cell faces are for the manipulator arms, periscopes, and observation windows. The observation windows measure 32 inches by 22 inches, and consist of 43-inch thick lead glass. Each hot cell observation window was served by a pair of master-slave manipulators (Lewis Research Center Staff 1959: 20-21).

Accessible areas include the Cold Work Room and the Manipulator Repair Shop. The remainder of the building is inaccessible (due to radiation), and includes seven Hot Cells, a Hot Dry Storage Area, and a Hot Work Area. Extant artifacts included eight sets of manipulator arms used by workers in the Cold Work Room to handle and manipulate materials and experiments inside the Hot Cells (Plate 4). All eight sets of manipulator arms are Master-Slave Manipulators manufactured by Central Research Laboratories, Inc., of Red Wing, Minnesota. Two different models, Model 8 and Model D, are present. The slave end of each manipulator arm is located within a Hot Cell and is contaminated by radiation, while the master end, located in the Cold Work Room, is uncontaminated.

The Master-Slave Manipulators were used to handle reactor elements and experiments inside the Hot Cells. The cells were fitted with a variety of tools and equipment for cutting, measuring, weighing, fracturing, and otherwise manipulating and handling irradiated materials. The Manipulators provided a safe means for accomplishing these various tasks. Additionally, several of the Hot Cells were fitted with wall periscopes, stereomicroscopes and other equipment to aid in the testing and analysis of experiments and other irradiated materials. Cell No. 1 has a Kollmorgen Corporation wall periscope manufactured in Northampton, Massachusetts (Plate 5). Cells No. 2 and 7 have an Instrument Tech, Inc., wall periscope, manufactured in West Springfield, Massachusetts, and installed in 1970. Cell No. 3 has a Bausch & Lomb Remote Control Metallograph and Stereomicroscope, manufactured in 1960 in Rochester, New York (Plate 6). Cell No. 5 has a microscope of unknown manufacture, while Cell No. 6 has a Unitron microscope.

Other extant equipment in the Hot Laboratory includes a series of Manipulator Control Consoles (Model 302-E) manufactured by General Mills, Inc., in Minneapolis. These units are presently stored in the Manipulator Repair Shop (Plate 7). They were originally used to operate the General Mills Manipulators in two of the Hot Cells.

Reactor Office and Laboratory Building (Building 1141)

The Reactor Office and Laboratory Building is a 3-story building attached to the west façade of the Reactor Building (see Figure 7, Plate 8). The Office and Laboratory

Building housed offices, repair shops, radiochemistry laboratories, and other support functions. When the PBRF shut down in 1973 the majority of the equipment and laboratories was removed. Extant equipment includes fume hoods, sinks, drain lines, and sumps.

Evaluation of Artifacts

Reactor Building

Extant artifacts within the containment vessel include electronics used to monitor the reactor and experiments (Plate 9). None of this equipment appears to be unique to the PBRF. Additional equipment used to insert experiments into the reactor is contaminated and does not appear suitable for preservation (Plate 10).

The most significant and unique artifacts within the Reactor Building are control and monitoring devices located in the Main Control Room. Elements of the control rooms for both the main reactor and the Mock-up Reactor have been removed for reuse and are no longer intact (Plate 11); however, the main control panel in the Main Control Room is largely intact and exemplifies the control and monitoring technology in use at the time of the PBRF's construction. The control panel is directly related to the operation of the reactor and appears to be largely unaltered from its original installation. As such it is an artifact that conveys the history and operation of the PBRF, while also representing the technology associated with the control and operation of research reactors in the early 1960s (Plates 12 and 13).

Additional artifacts within the Reactor Building that appear to be likely candidates for preservation include the Remote Monitoring Panel (Plate 14) and the Reactor Water Systems Panel (Plate 15) in the Main Control Room. Both are schematic diagrams of the reactor with light bulbs that indicate the condition of critical elements within the system. Like the control panel, these panels are directly related to the operation of the PBRF and illustrate the technology in use during the reactor's service life. Additionally, none of these artifacts would require decontamination prior to removal and preservation.

Hot Laboratory

All of the equipment and artifacts located in the Hot Laboratory were used to inspect, test, analyze, and handle irradiated material and experiments. They represent standard equipment used at most research reactors and are not uniquely associated with PBRF or the experiments conducted at the facility. None of these devices are "unique objects" as defined by NPG 4310. None of these artifacts can dramatically interpret the history or significance of the PBRF. Accordingly, none of these artifacts appear to be worthy of preservation.

Reactor Office and Laboratory Building

None of the extant objects in the Reactor Office and Laboratory Building meet the NPG 4310 definition of a historic artifact. The possible exception to this condition is a mass spectrometer and its controls located in Room 213A, a former Chemistry Laboratory (Plate 16). This unit appears relatively intact and is an interesting example of ca. 1960 test equipment. Small artifacts located in the Laboratory and Office Building that may be worthy of preservation include a series of light fixtures, similar to “exit” signs, that read

An extant artifact that relates to the social history of the PBRF is a blackboard located in an office in the Reactor Office and Laboratory Building that was illustrated prior to the closure of the facility by PBRF personnel (Plate 18). The blackboard is dominated by large block letters reading RIF, for “reduction in force.” A series of smaller cartoons and comments illustrate the dissatisfaction of PBRF personnel at the closure of the facility and suggests the esprit de corps of the engineers, scientists and technicians that worked at the PBRF. This blackboard appears worthy of preservation.

Reactor Model

Perhaps the most significant artifact associated with the PBRF is a large, scale model of the facility currently on display in the cafeteria at Plum Brook Station (Plate 19). This model depicts the Reactor Building (Plate 20) and the Hot Laboratory (Plate 21) in considerable detail. For the lay audience, the model is probably better at conveying the design and physical organization and operation of the PBRF than photographs or drawings. The model is clearly labeled and is readily interpreted. Features and elements that are partially hidden or difficult to view in photographs are clearly depicted (Plates 22, 23, and 24).

Recommendations

The principal artifact recommended for preservation is the large scale model of the PBRF presently on display in the Plum Brook Station cafeteria. This model offers the greatest opportunity for interpreting the history, operations, and significance of the PBRF. Other artifacts recommended for preservation include the Main Control Panel, the Remote Monitoring Panel, and the Reactor Water Systems Panel, all located in the Main Control on the mezzanine of the Reactor Building. The mass spectrometer and its controls, located in Room 213A of the Office and Laboratory Building, while not uniquely related to the operation of the PBRF, is nevertheless a significant piece of scientific equipment and likely worthy of preservation. There are a variety of small scale elements, including the “REACTOR ON” signs, that could be easily preserved. The “RIF” blackboard in the Office and Laboratory Building is a unique artifact related to the social history of the PBRF and its closure. This artifact is also worthy of preservation.

The extant equipment in the Hot Laboratory, most notably the master-slave manipulator arms, hot cell periscopes, and various testing and analytical devices assigned to the hot cells, are not considered worthy of preservation. These artifacts are typical of the handling and testing equipment used at most research reactors, and are not uniquely associated with the operation of the PBRF facility.

As noted above, NASA Procedures and Guidelines NPG 4310 *Identification and Disposition of NASA Artifacts* (16 March 1999) stipulates that the National Air and Space Museum (NASM) is responsible for the custody, protection, exhibition, and loan of artifacts received from federal agencies. Repositories for NASA artifacts are identified with the assistance of the NASM so as to most effectively inform the public regarding NASA’s endeavors. Artifacts are offered to the NASM when their utility to NASA has been exhausted.

The permanent location for artifacts that the NASM wishes to acquire from the PBRF is subject to discussion and negotiation between NASA and the NASM. Artifacts could be displayed at Plum Brook Station, NASA Glenn, or at some other institution deemed suitable by all parties.

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Plate 1. View of Reactor Building and Hot Laboratory Building to northeast.

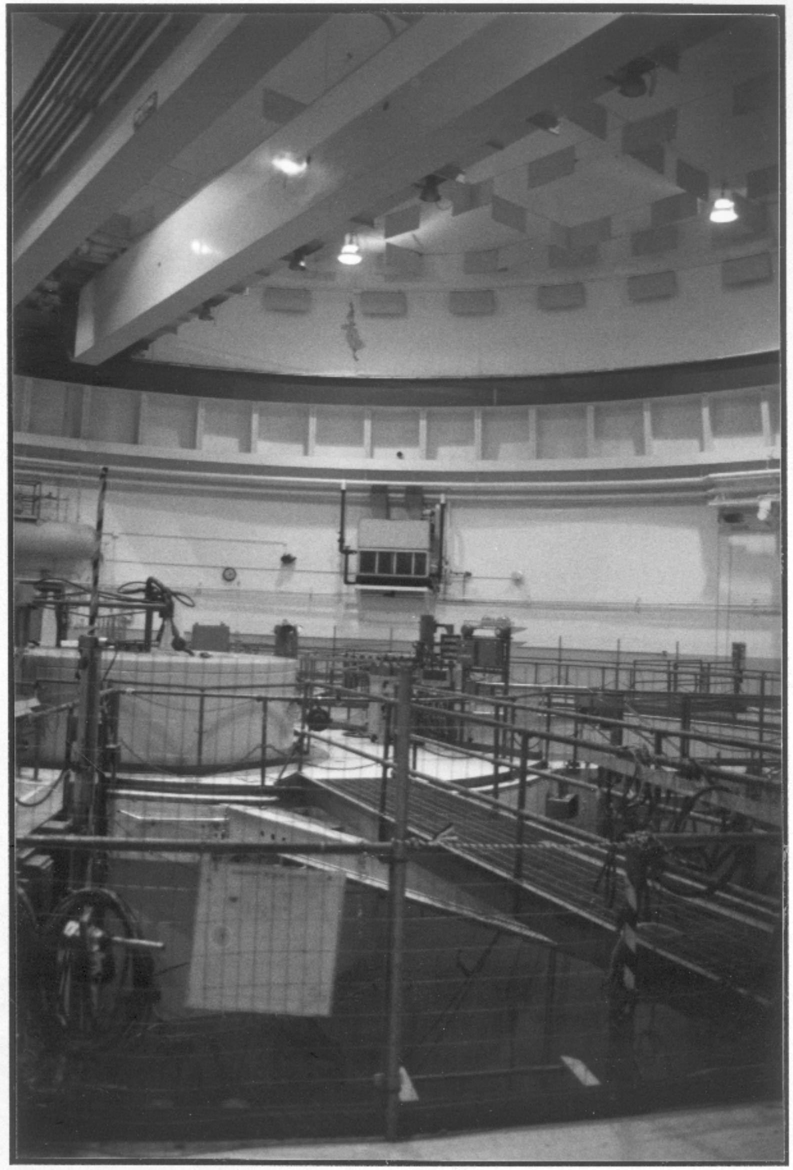

Plate 2. View of containment vessel to northeast.

Plate 3. View of Hot Laboratory Building to southeast.

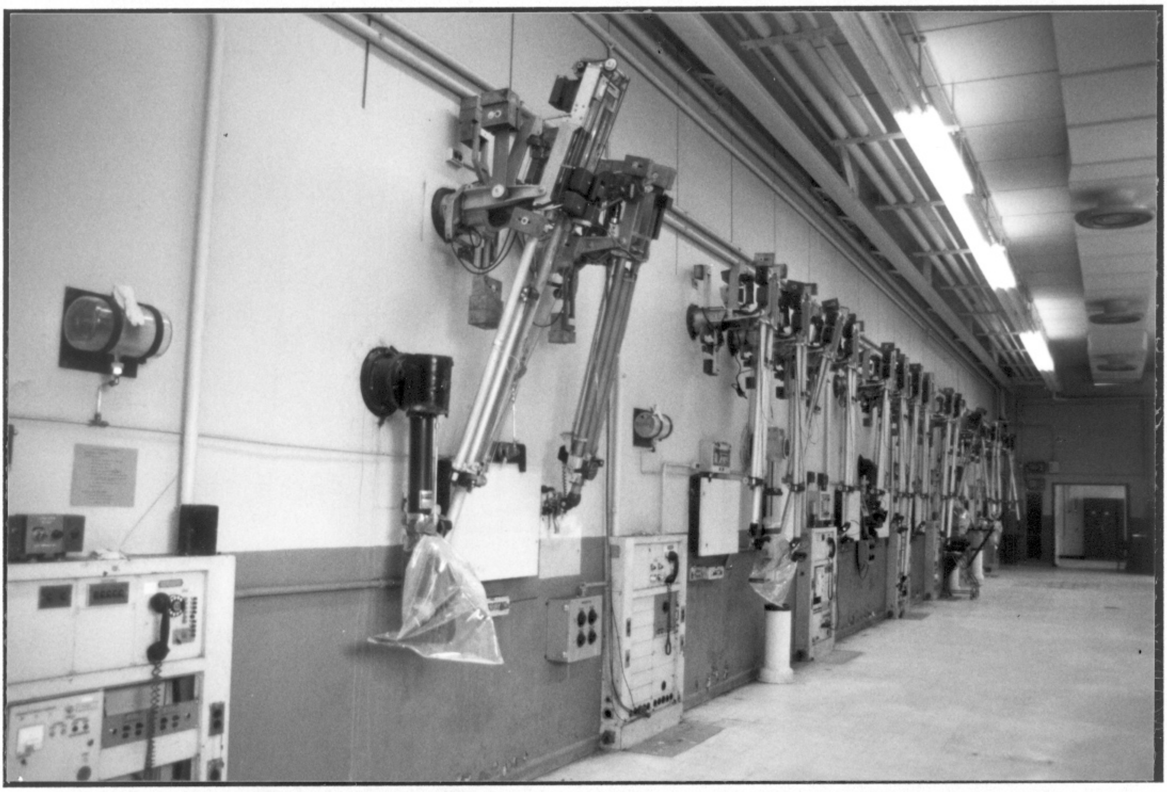

Plate 4. View of Hot Laboratory Building Cold Work Room to south. Note manipulator arms.

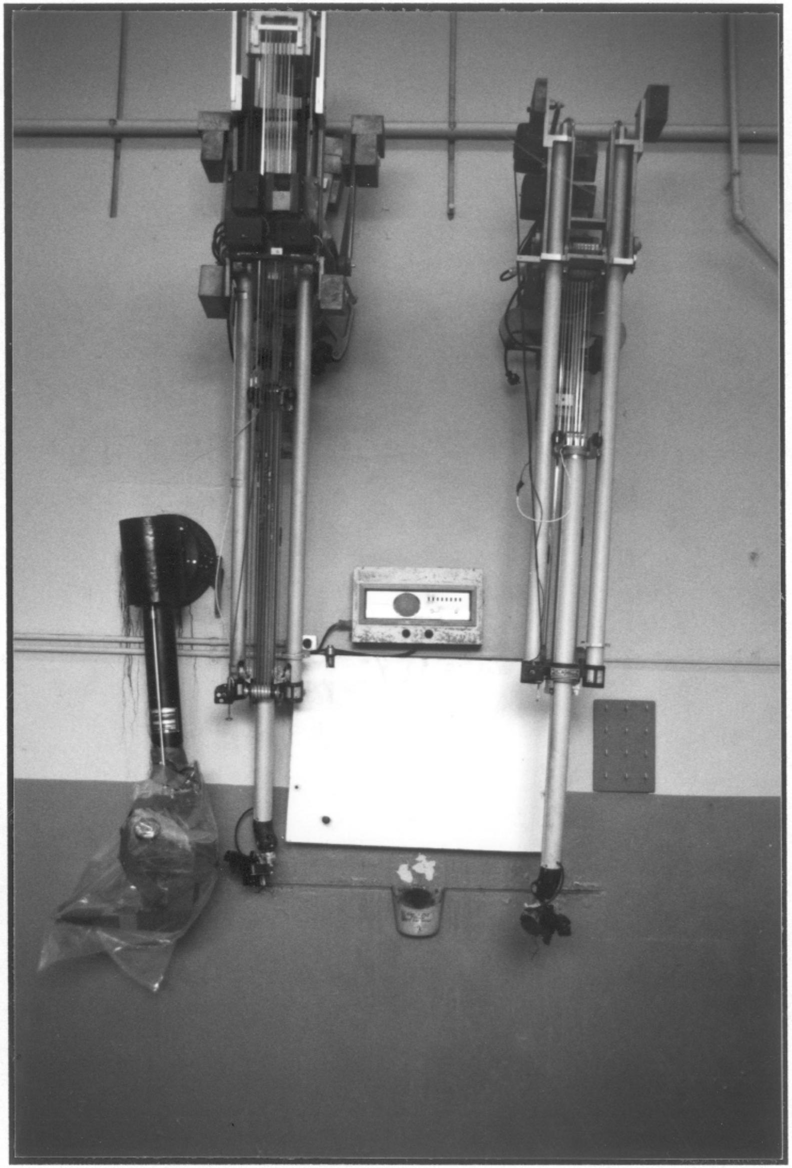

Plate 5. Detail view to east of manipulator arms.

Plate 6. Detail view to east of Bausch & Lomb Remote Control Metallograph and Stereomicrocope at hot cell no. 3.

Plate 7. Manipulator control consoles in storage in Manipulator Repair Shop.

Plate 8. View of Reactor Office and Laboratory Building to northeast.

Plate 9. Monitoring equipment inside Containment Vessel.

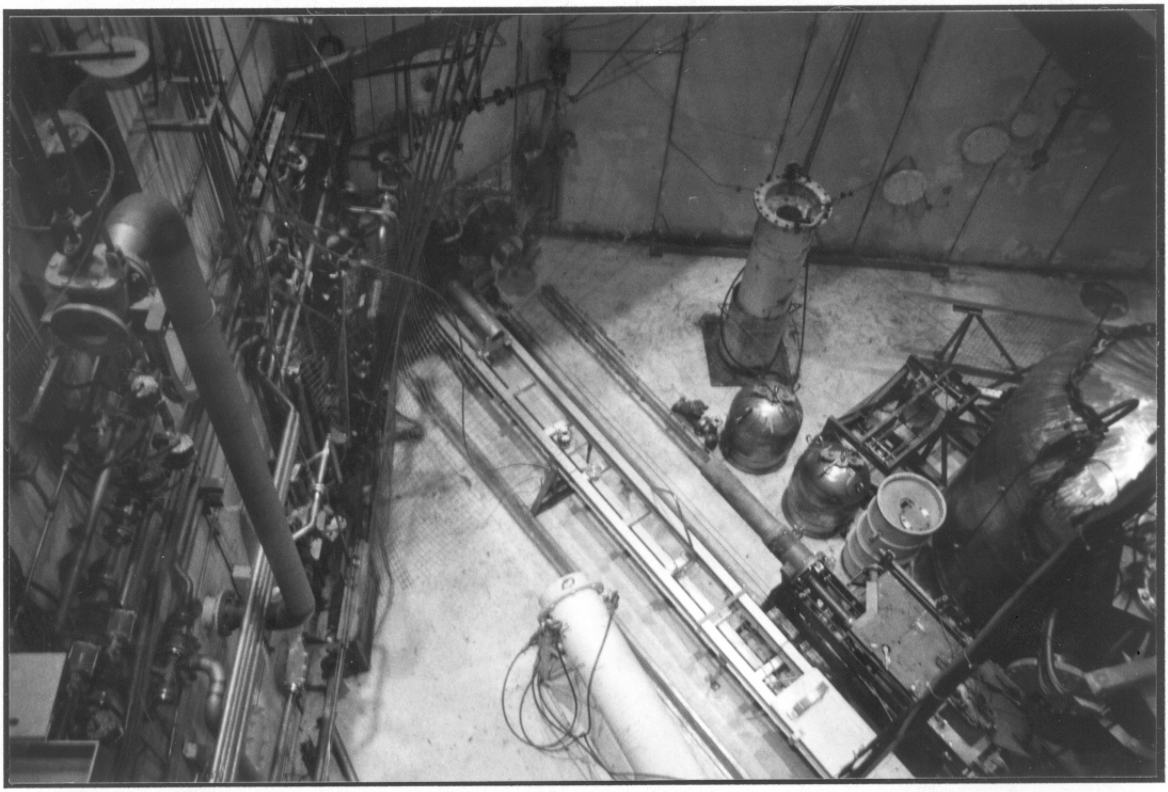

Plate 10. View down into area used for insertion of experiments into reactor.

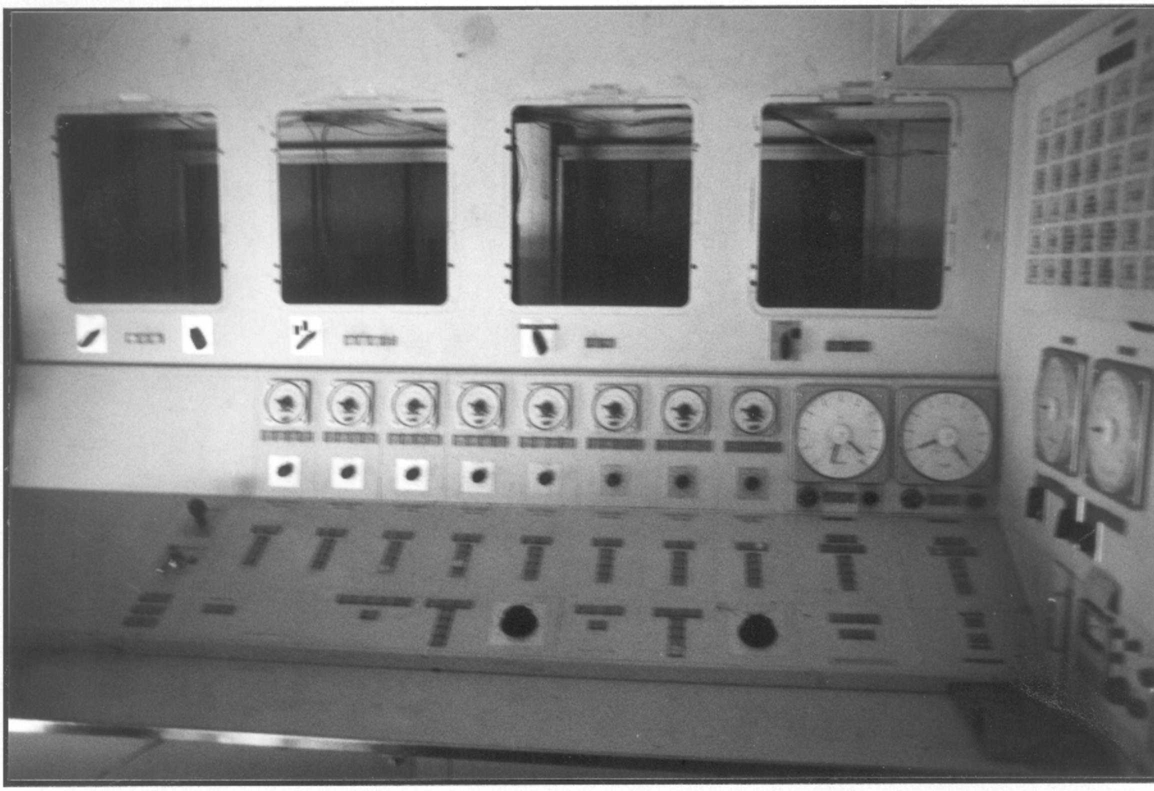

Plate 11. View of Mock-up Reactor Control Panel.

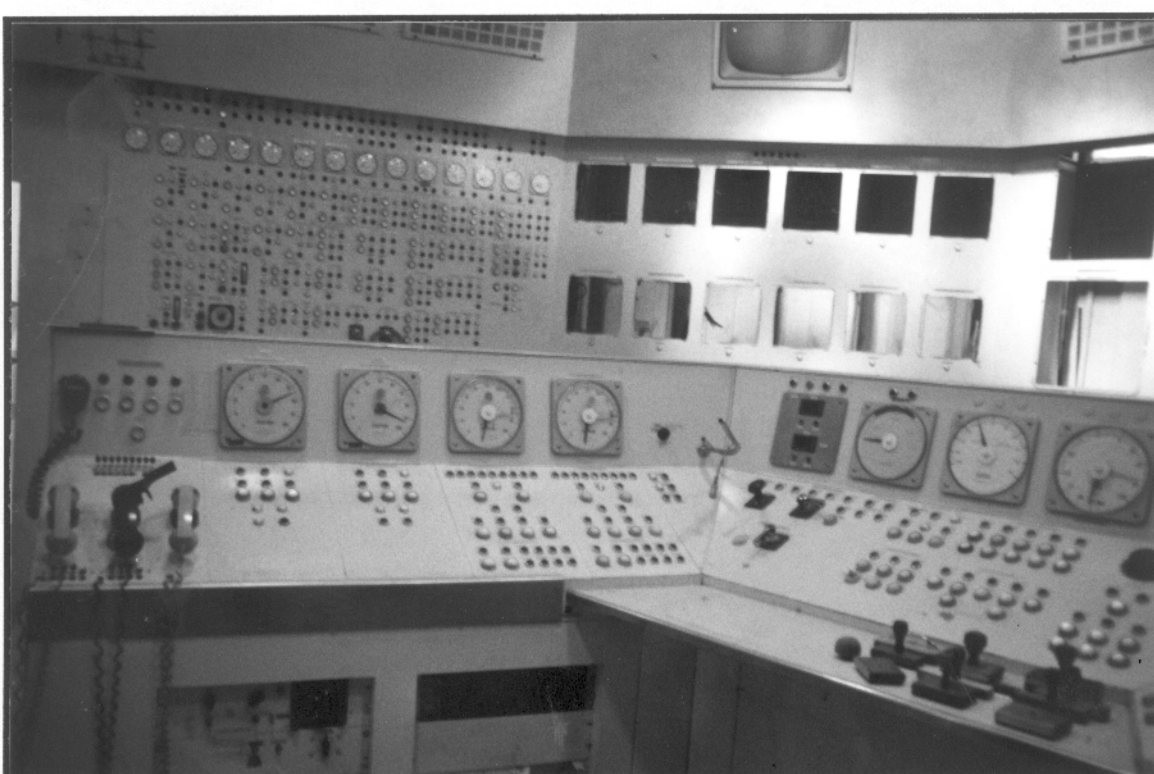

Plate 12. View of Main Control Panel to northwest.

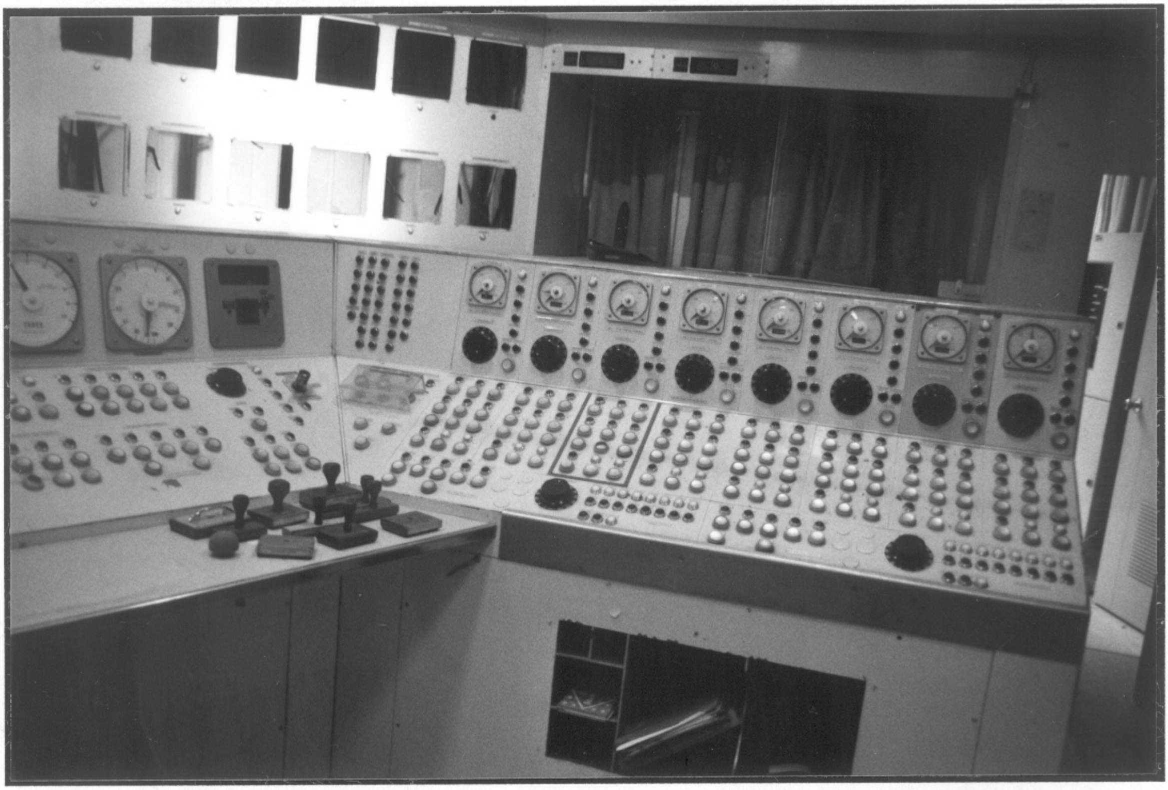

Plate 13. View of Main Control Panel to north.

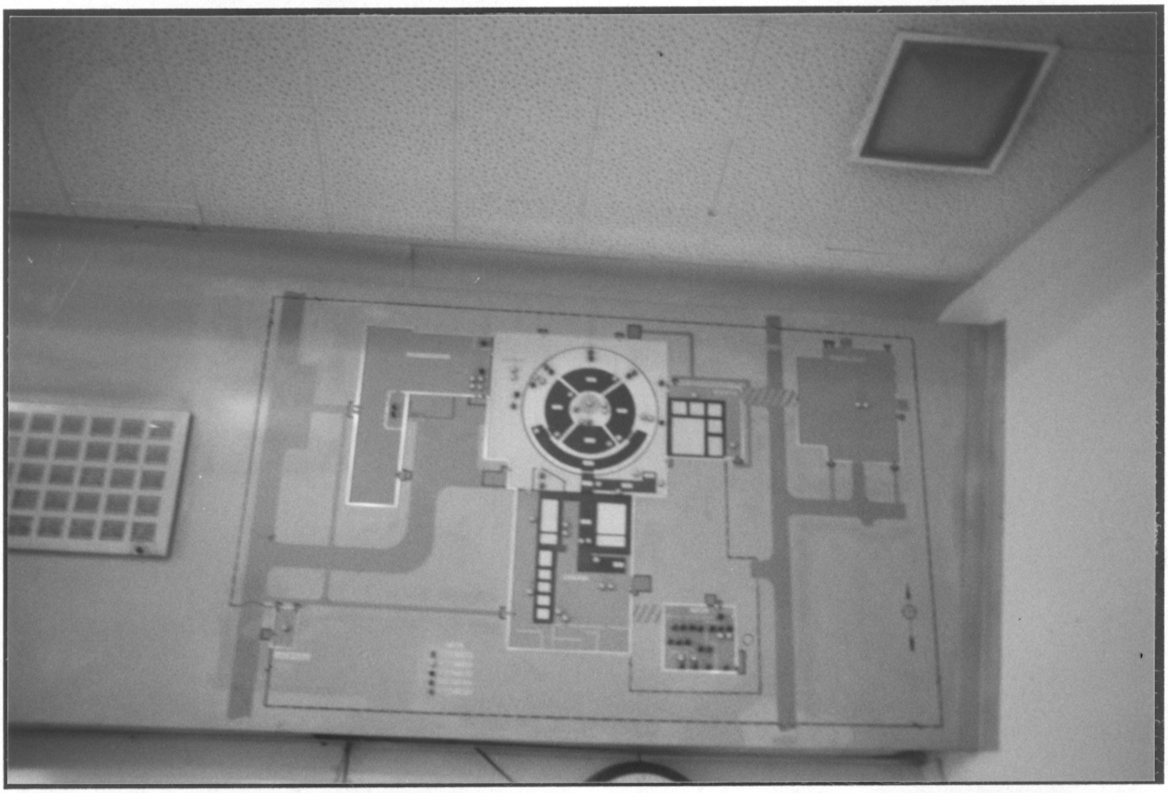

Plate 14. View of Remote Monitoring Panel.

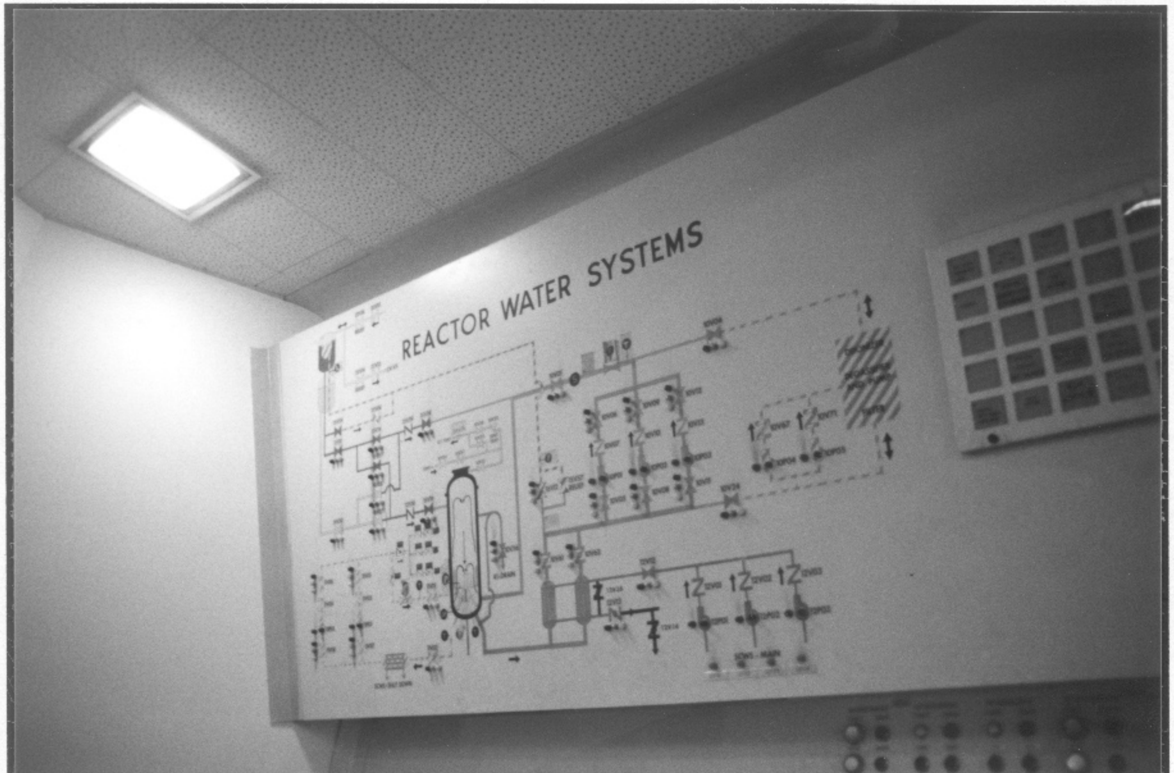

Plate 15. View of Reactor Water Systems Panel.

Plate 16. View of mass spectrometer and control panels.

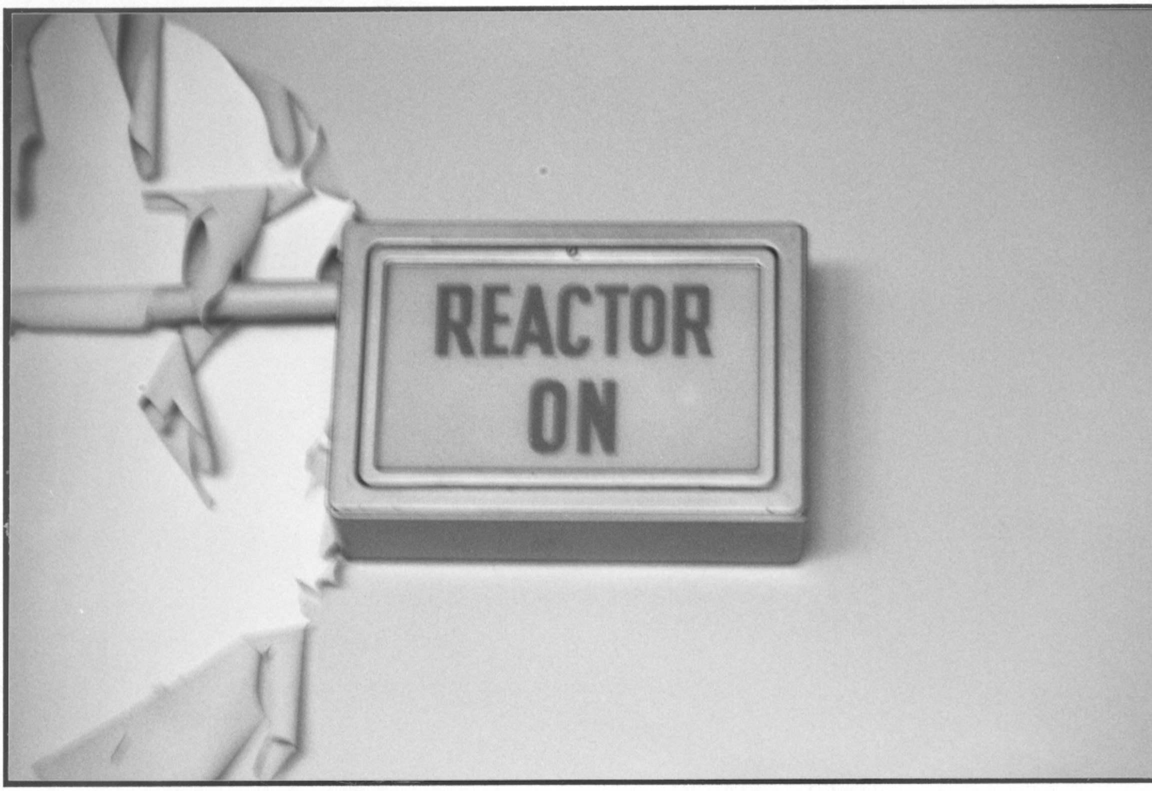

Plate 17. View of typical "Reactor On" sign.

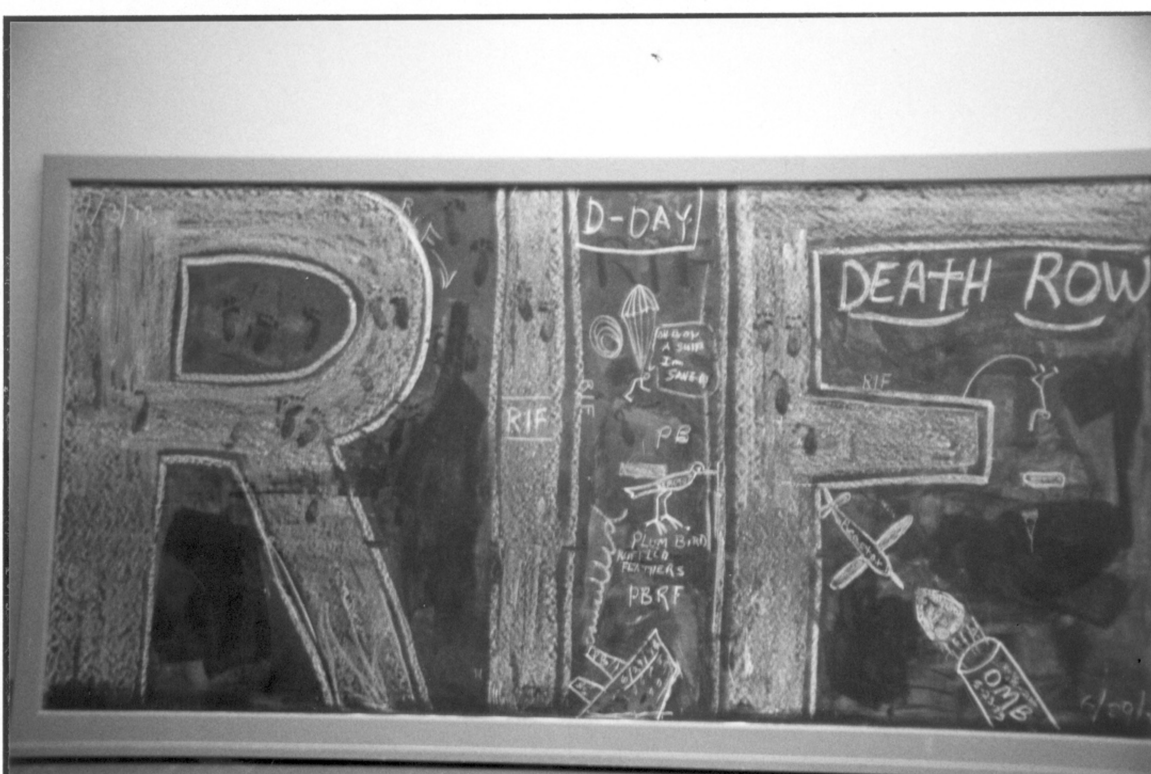

Plate 18. View of "RIF" blackboard.

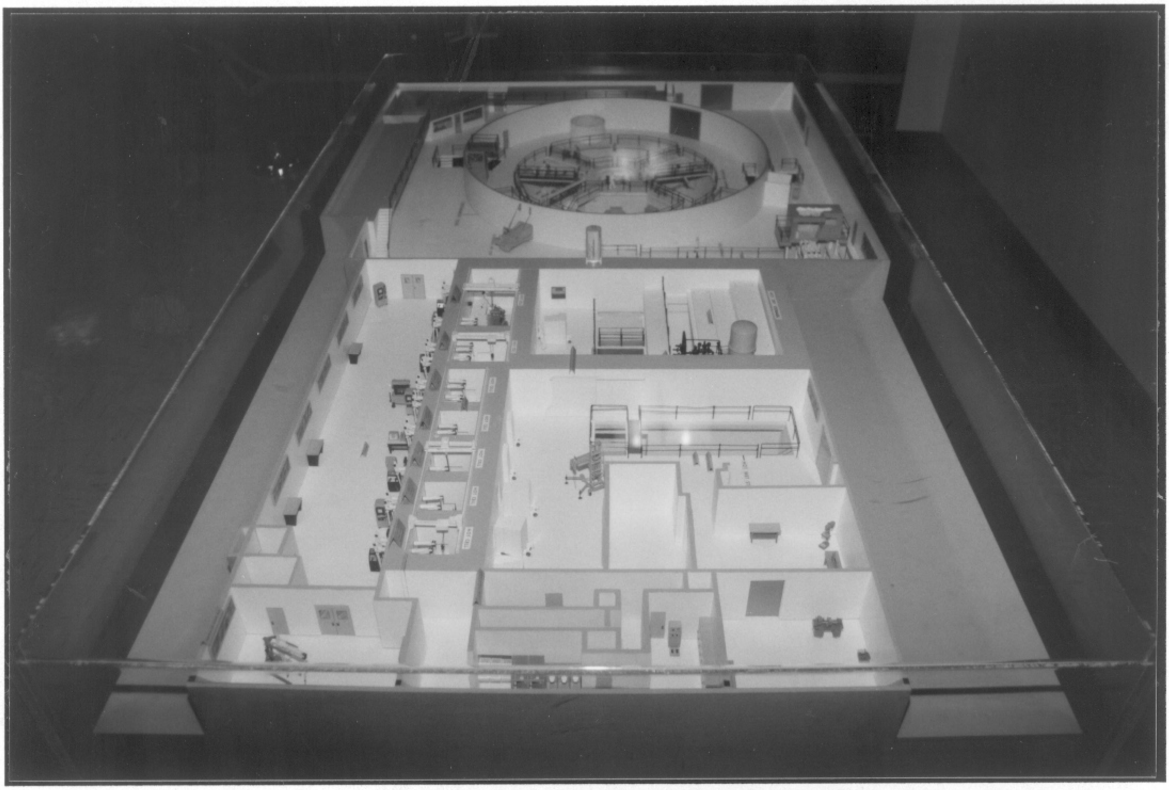

Plate 19. Overall view of Reactor Model.

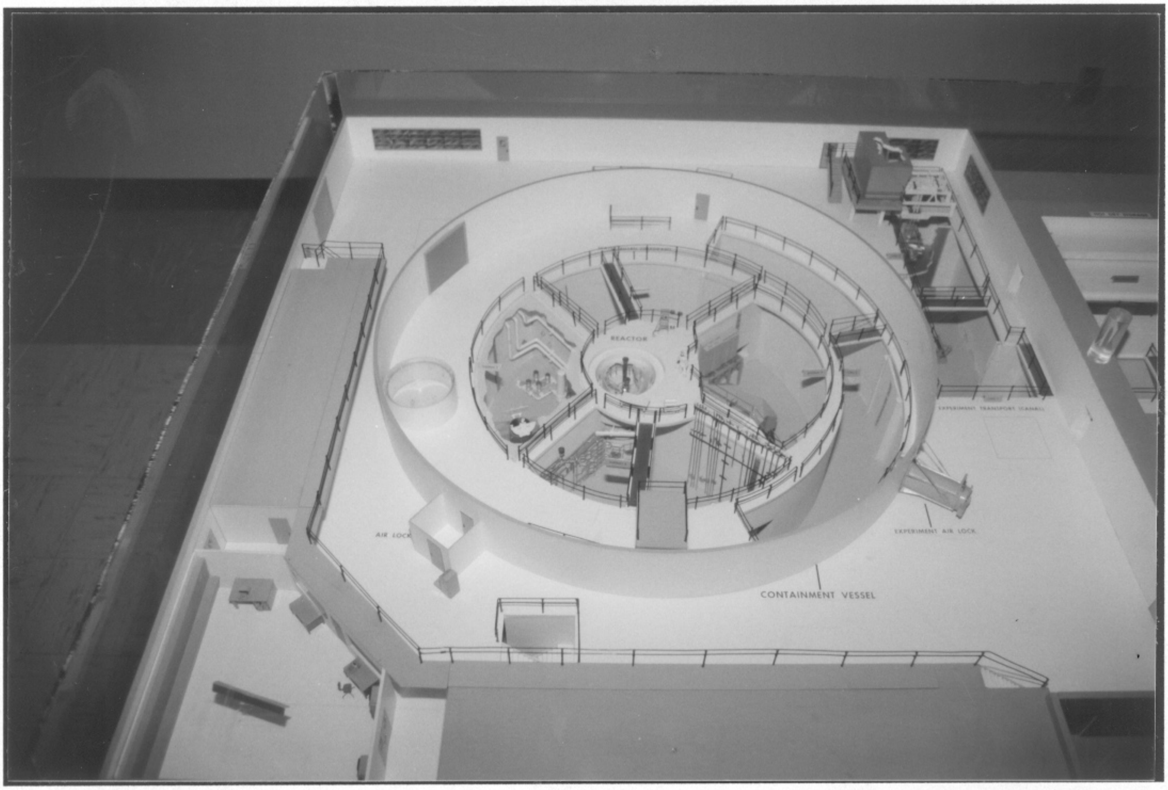

Plate 20. View of Reactor Building portion of the Reactor Model.

Plate 21. View of Hot Laboratory portion of Reactor Model.

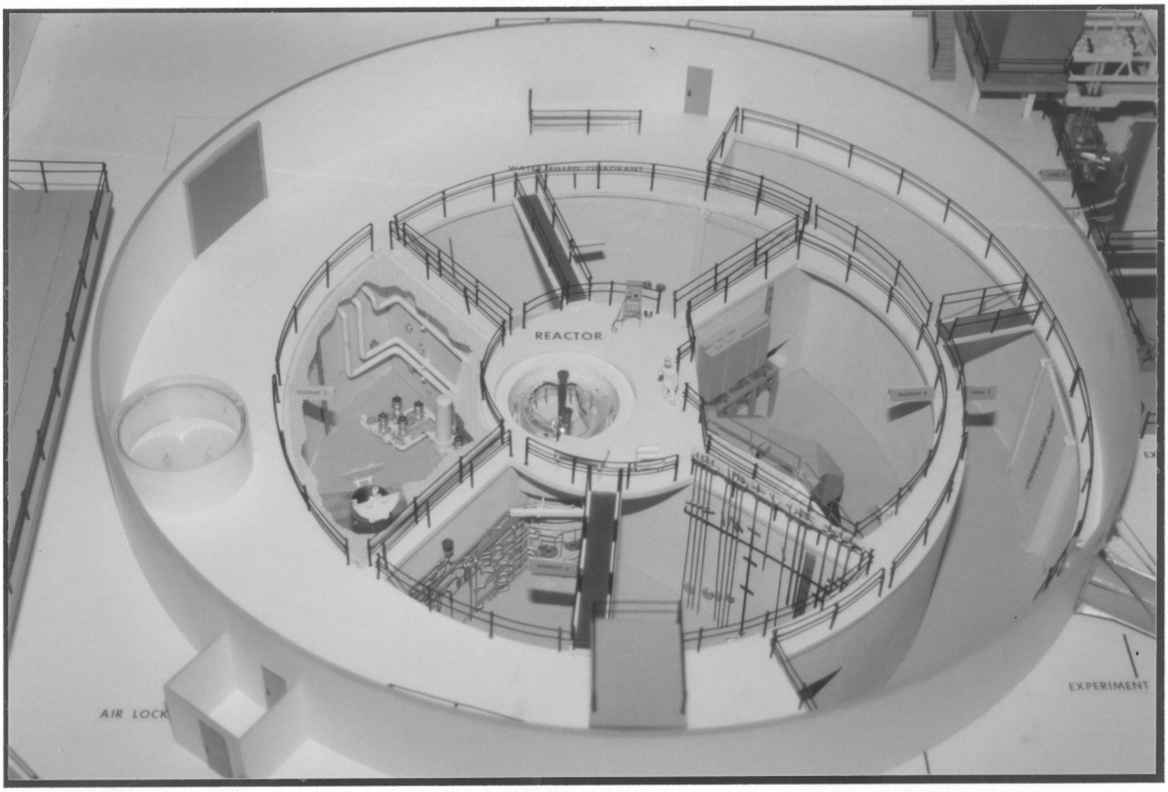

Plate 22. Detail view of Containment Vessel portion of Reactor Model.

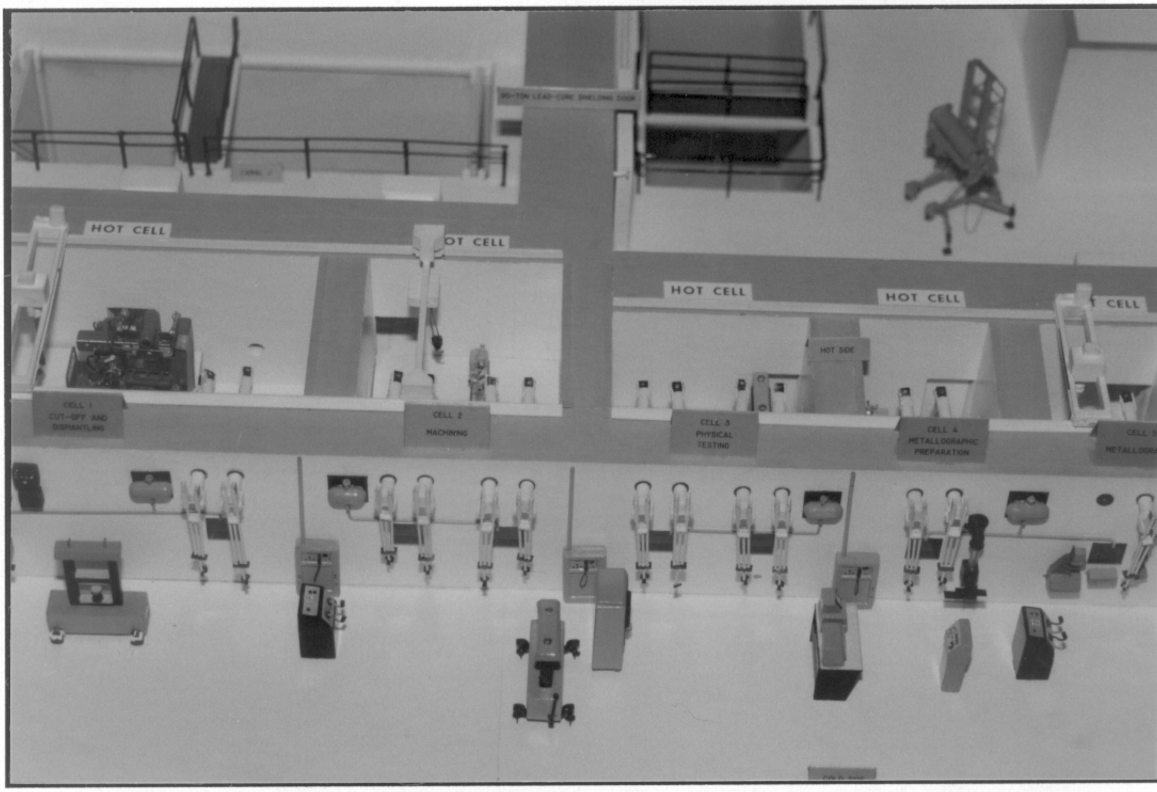

Plate 23. Detail view of Cold Work Room and Hot Cells portion of Reactor Model.

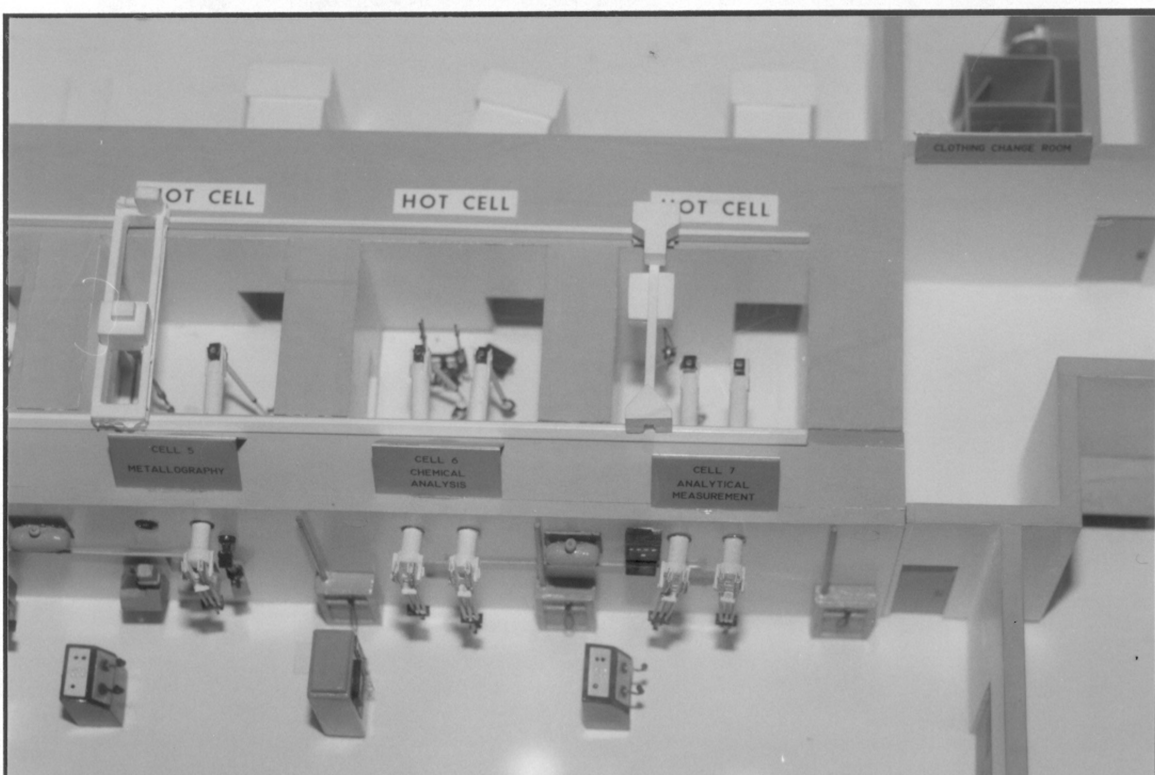

Plate 24. Detail view of Hot Cells portion of Reactor Model.